Assessment of the limit of initial-condition useful skill in interannual climate prediction

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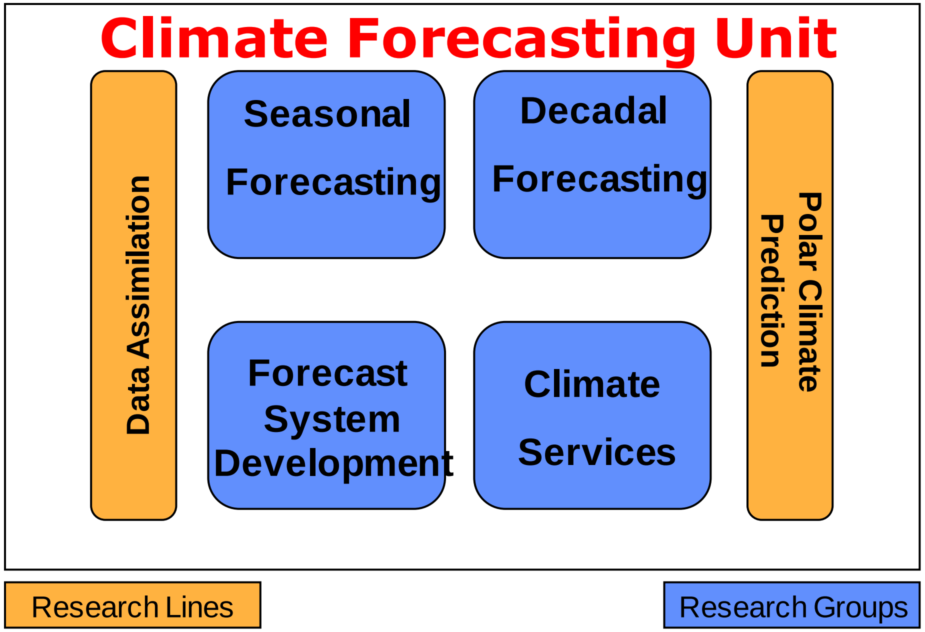
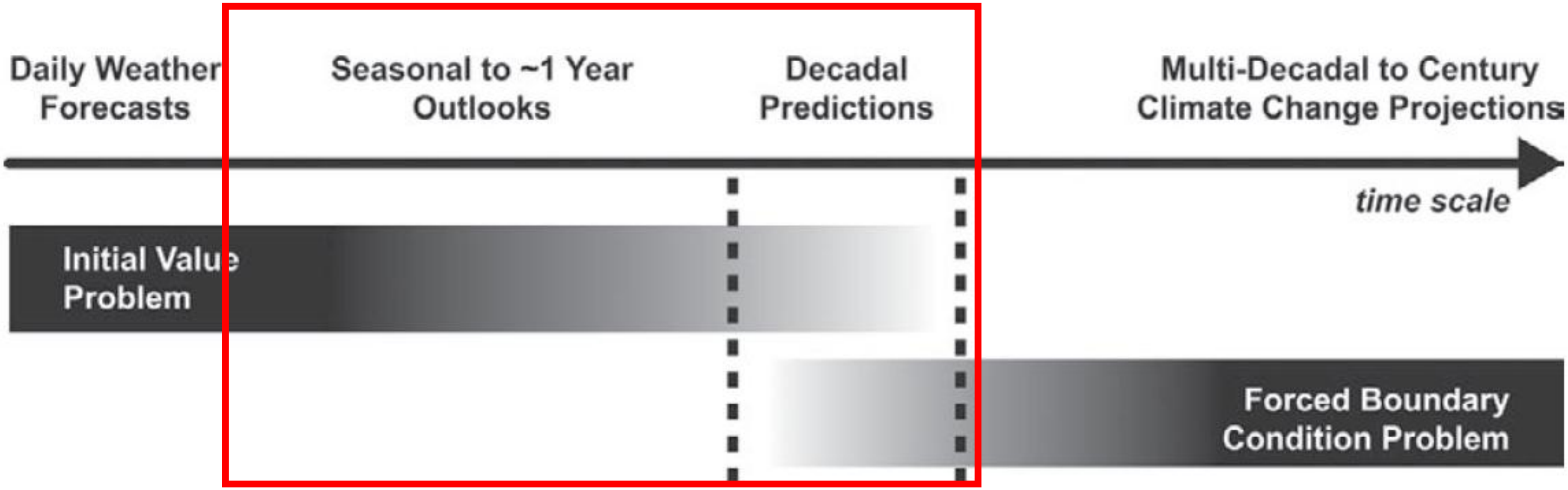


Climate time scales

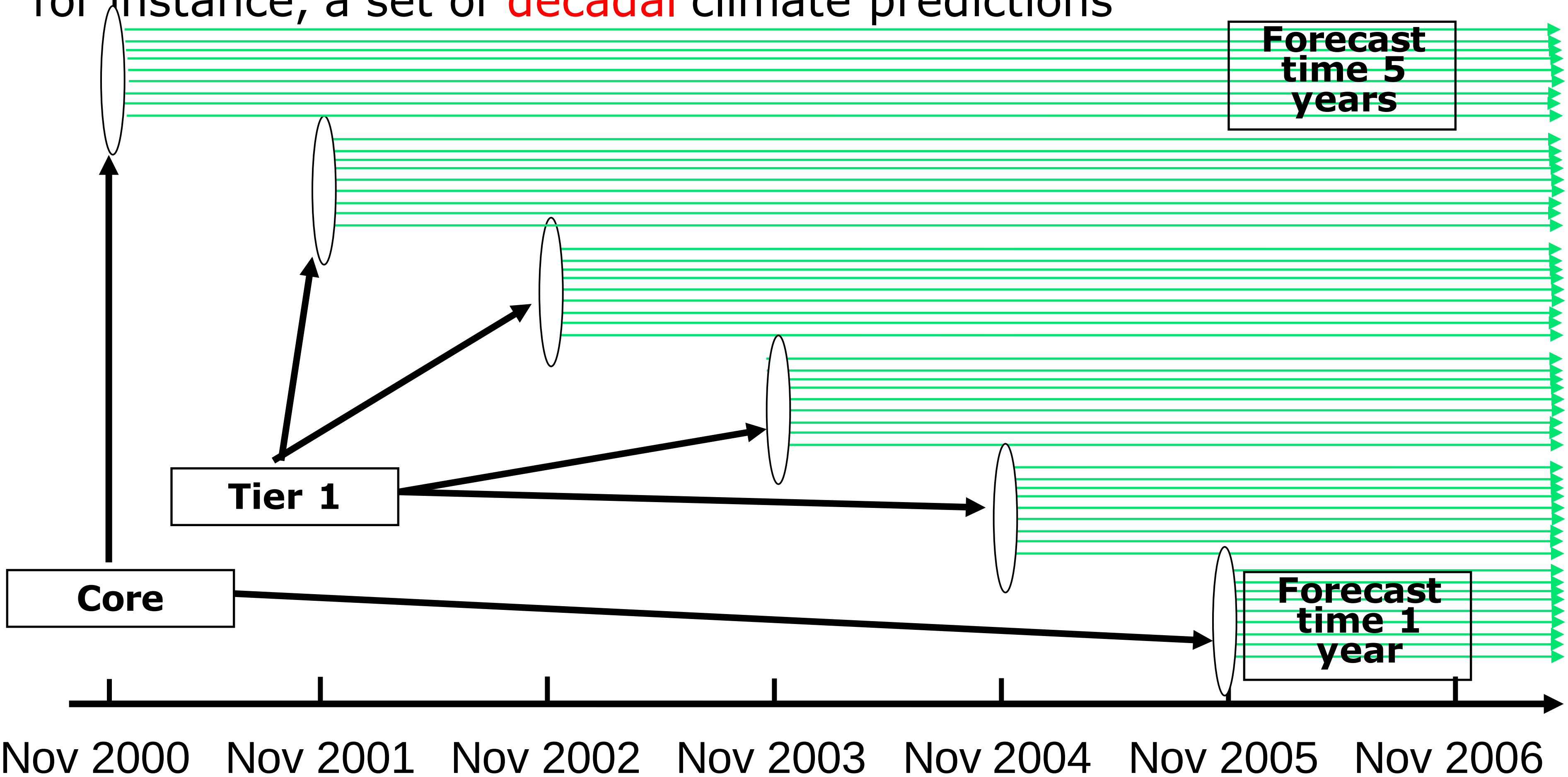
Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialisation and systematic comparison with a simultaneous reference.



Meehl et al. (2009)

Climate predictions

Assume an ensemble forecast system with an initialized ESM to perform, for instance, a set of decadal climate predictions



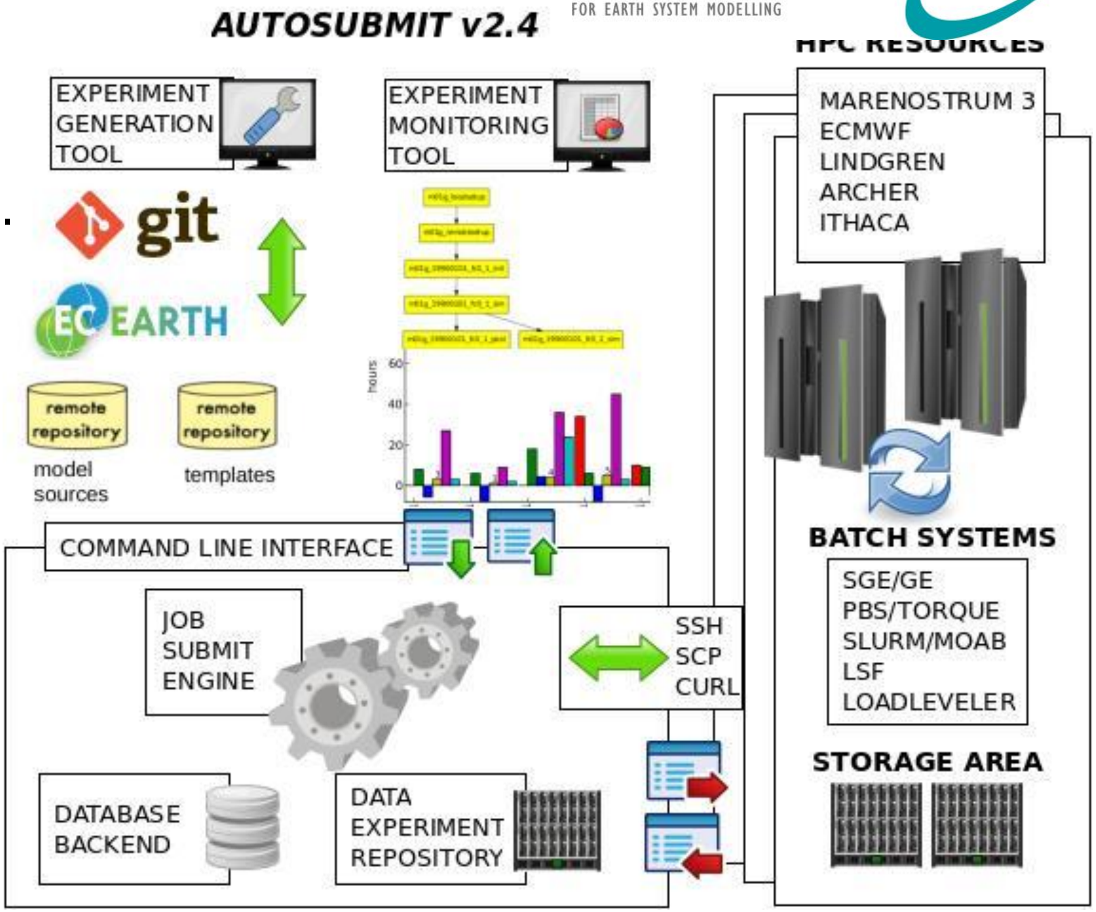
Predictions are also made with empirical forecast systems to be used as benchmarks and to detect untapped sources of predictability.

Autosubmit

Autosubmit acts as a wrapper to run a climate experiment on a HPC. The experiment is a sequence of jobs that it submits, manages and monitors. When a job is complete, the next one can be executed.

- Divided in 3 phases: ExpID assign, experiment creation (including access to a GIT repository), run.
- Separation experiment/autosubmit codes.
- Config files for autosubmit and experiment.
- Database for experiment information.
- Common templates for all platforms.
- Fault tolerance, recovery after crashes.
- Dealing with a list of schedulers and communication protocols.
- Automatic run statistics.

Each job has a colour in the monitoring tool: yellow=completed, green=running, blue=pending, etc.



Climate predictions

Climate prediction allows running jobs independently by wrapping together ensemble members for different start dates. This is not just trivial parallelisation.

EC-Earth3 at Lindgren, PDC

Number of Start Dates		1	5	10	10	20
Number of Members		1	5	5	10	10
Number of Independent Simulations		1	25	50	100	200
T159-ORCA1	Cores	144	3600	7200	14400	28800
	Wall-clock Time (Hours) / year	5	5	5	5	5
	CPU Time (Hours) / year	720	18000	36000	72000	144000
	Output Size (GB) / year	10,80	480	960	1920	3840
T255-ORCA1	Cores	360	9000	18000	36000	72000
	Wall-clock Time (Hours) / year	5	5	5	5	5
	CPU Time (Hours) / year	1800	45000	90000	180000	360000
	Output Size (GB) / year	19,20	5184	10368	20736	41472
T799-ORCA025	Cores	1104	27600	55200	110400	220800
	Wall-clock Time (Hours) / year	40	40	40	40	40
	CPU Time (Hours) / year	44160	1104000	2208000	4416000	8832000
	Output Size (GB) / year	256,80	6420	12840	25680	51360

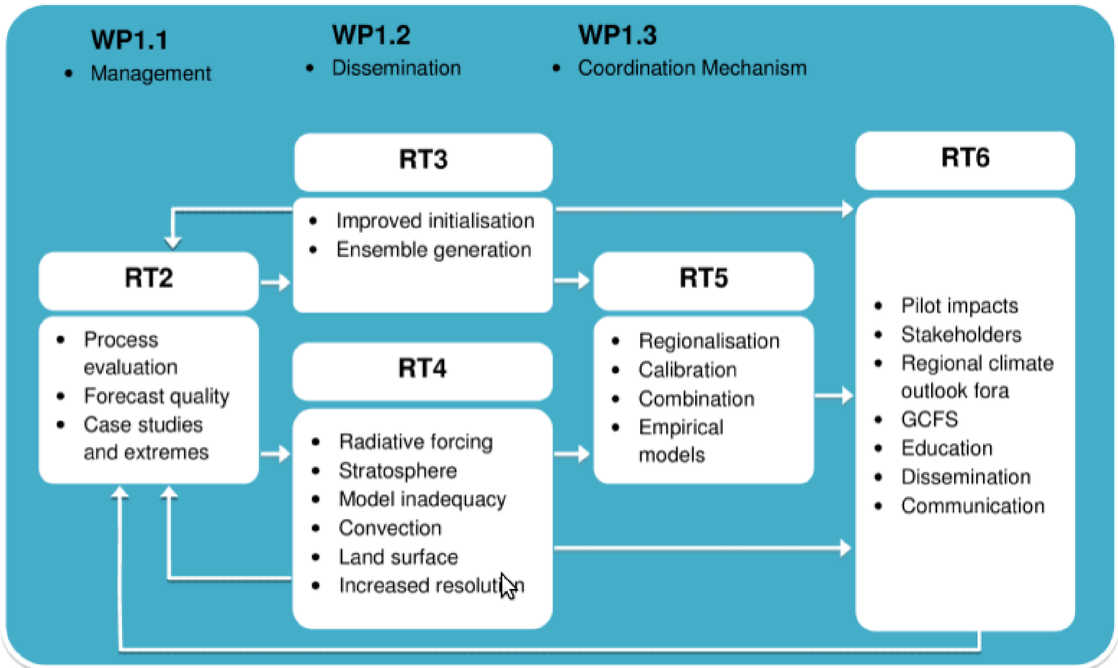
Some open fronts

- Work on initialisation: initial conditions for all components (including better ocean), better ensemble generation, etc. Link to observational and reanalysis efforts.
- Model improvement: leverage knowledge and resources from modelling at other time scales, drift reduction. More efficient codes and adequate computing resources.
- Calibration and combination: empirical prediction (better use of current benchmarks), local knowledge.
- Forecast quality assessment: scores closer to the user, reliability as a main target, process-based verification.
- Improving physical processes: sea ice, projections of volcanic and anthropogenic aerosols, vegetation/land, …
- More sensitivity to the users' needs: going beyond downscaling, better documentation (e.g. use the IPCC language), demonstration of value and outreach.

SPECS FP7, overall strategy

SPECS will deliver *a new generation of European climate forecast systems, including initialised Earth System Models (ESMs) and efficient regionalisation tools to produce quasi-operational and actionable local climate information over land at seasonal-to-decadal time scales with improved forecast quality and a focus on extreme climate events, and provide an enhanced communication protocol and services to satisfy the climate information needs of a wide range of public and private stakeholders.*

Forecast System	Project Partners
CNRM-CM5	CNRM, CERFACS
EC-Earth	KNMI, SMHI, IC3, ENEA
IFS/NEMO	ECMWF, UOXF
IPSL-CM5	CNRS
MPI-ESM	MPG, UniHH
UM	UKMET



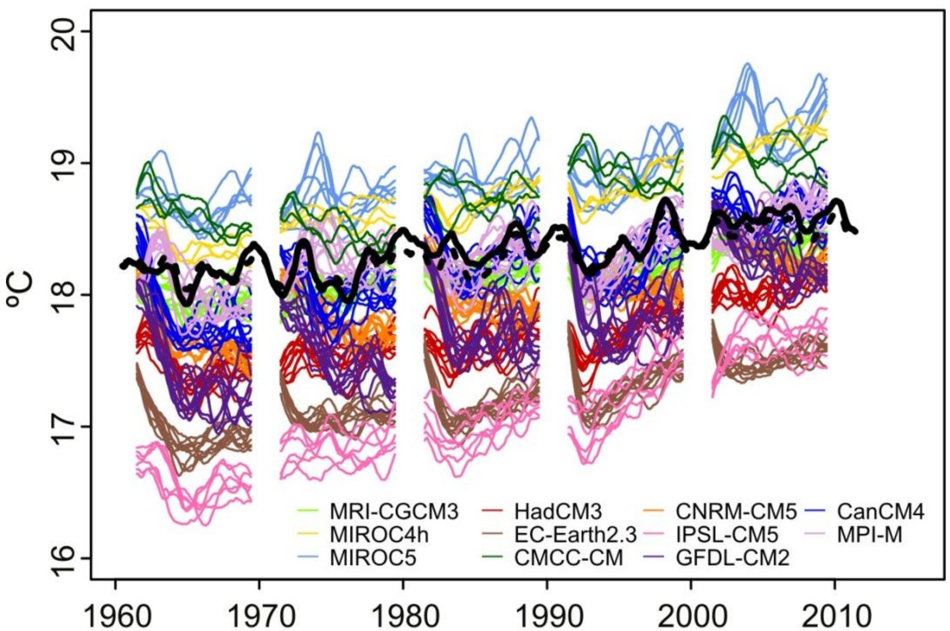
WP1.1: Management
WP1.2: Dissemination
WP1.3: Coordination across EUPORIAS, NACLIM & SPECS
RT2: Evaluation of current s2d forecast systems
RT3: Forecast strategies
RT4: Improved systems
RT5: Calibrated predictions at the local scale

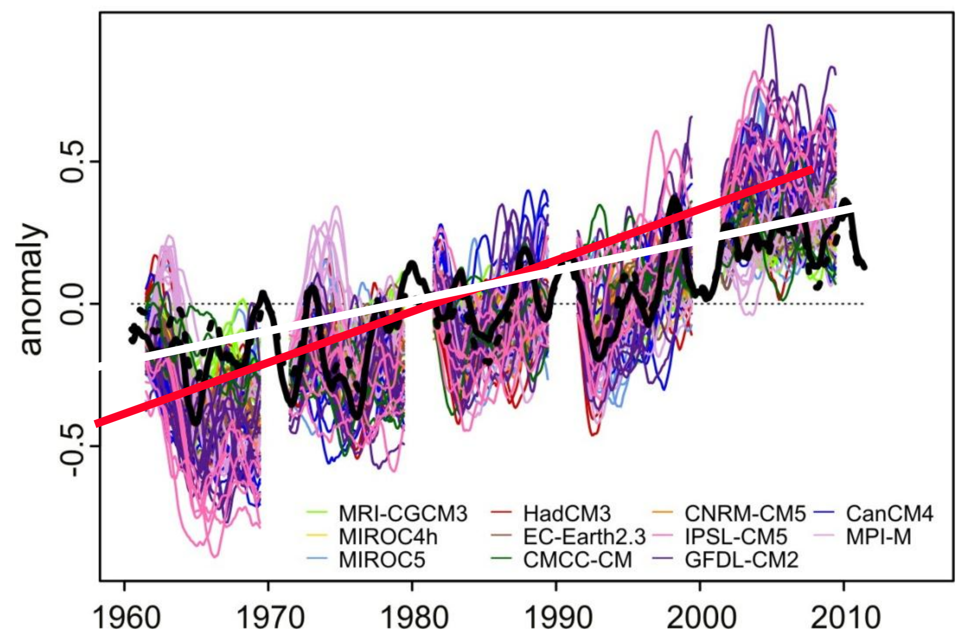
SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Shock, drift and systematic error

Global mean near-surface air temperature over the ocean (*one-year running mean applied*) from the CMIP5 hindcasts. Each system is shown with a different colour. NCEP and ERA40/Int used as reference.

The systematic error is very different from one system to another.



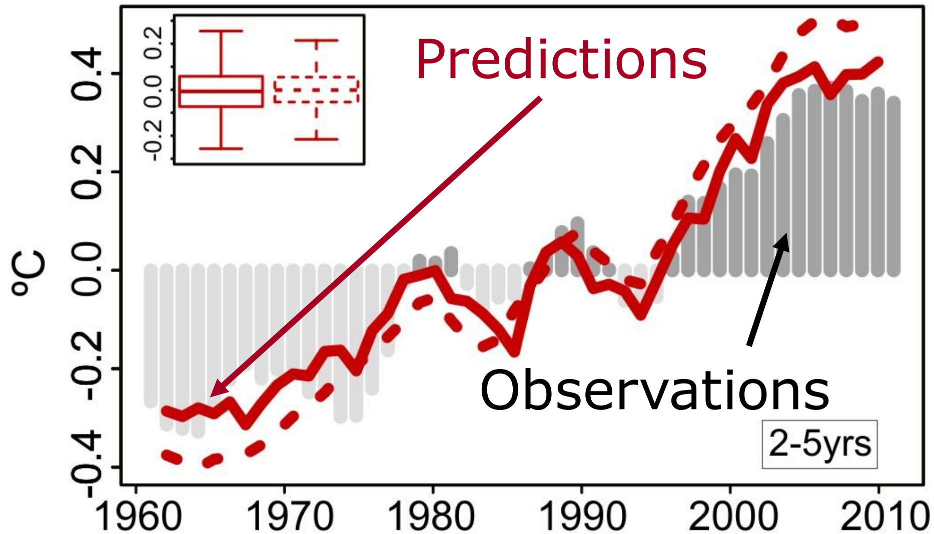


IPCC AR5 WGI (2013)

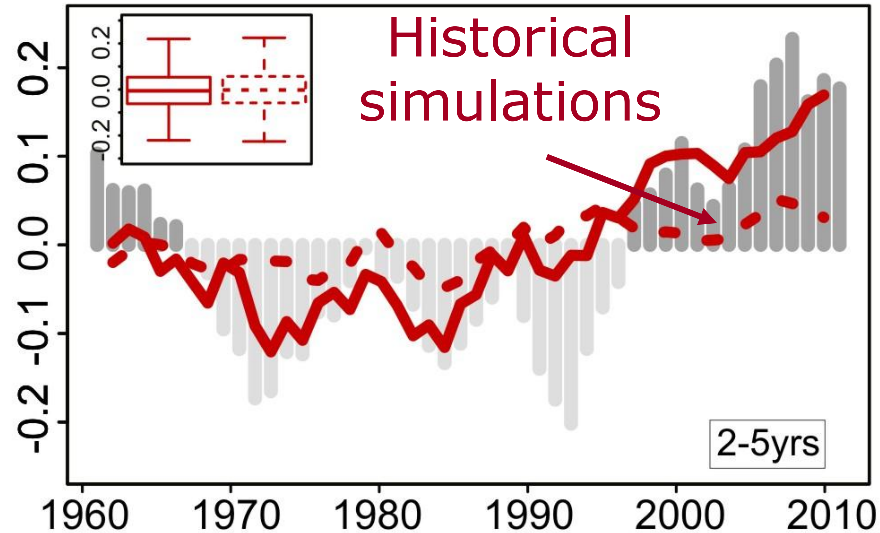
CMIP5 decadal predictions

CMIP5 decadal predictions. Global-mean t2m and AMV against GHCN/ERSST3b for forecast years 2-5. **The initialised experiments reproduce the GMST trends and the AMV variability and suggest that initialisation corrects the forced model trend and phases in some of the internal variability.**

Global mean surface atmospheric temperature



Atlantic multidecadal variability (AMV)



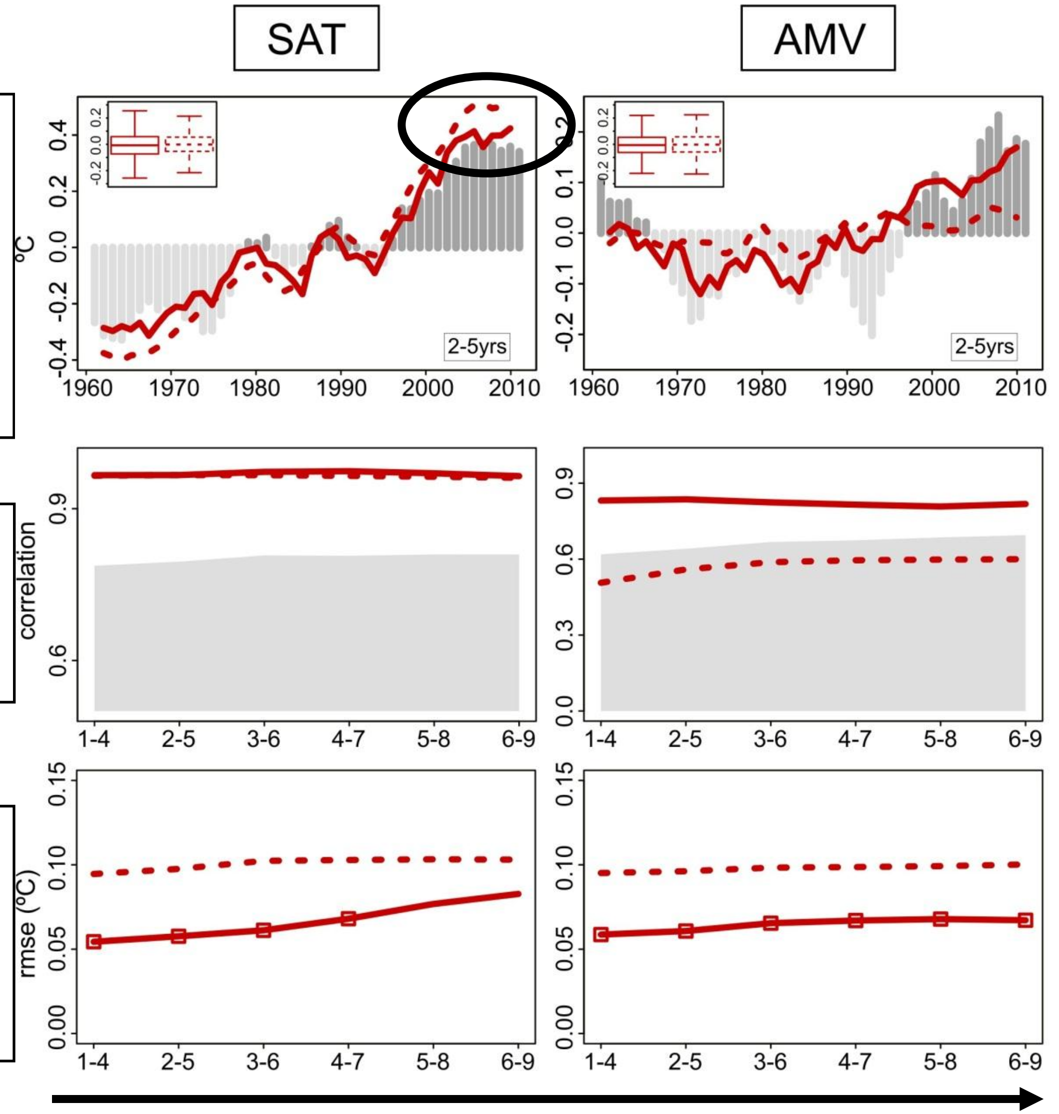
Doblas-Reyes et al. (2013)

CMIP5 decadal predictions

Predictions (2-5 forecast years) from the CMIP5 multi-model (6 systems, initialized solid, historical and RCP4.5 dashed) over 1960-2005 for global-mean temperature and the Atlantic multi-decadal variability. GISS and ERSST data used as reference.

Correlation of the ensemble-mean prediction as a function of forecast time. Grey area for the 95% confidence level.

Root mean square error, where dots represent the forecast times for which Init and NoInit are significantly different at 95% confidence level.

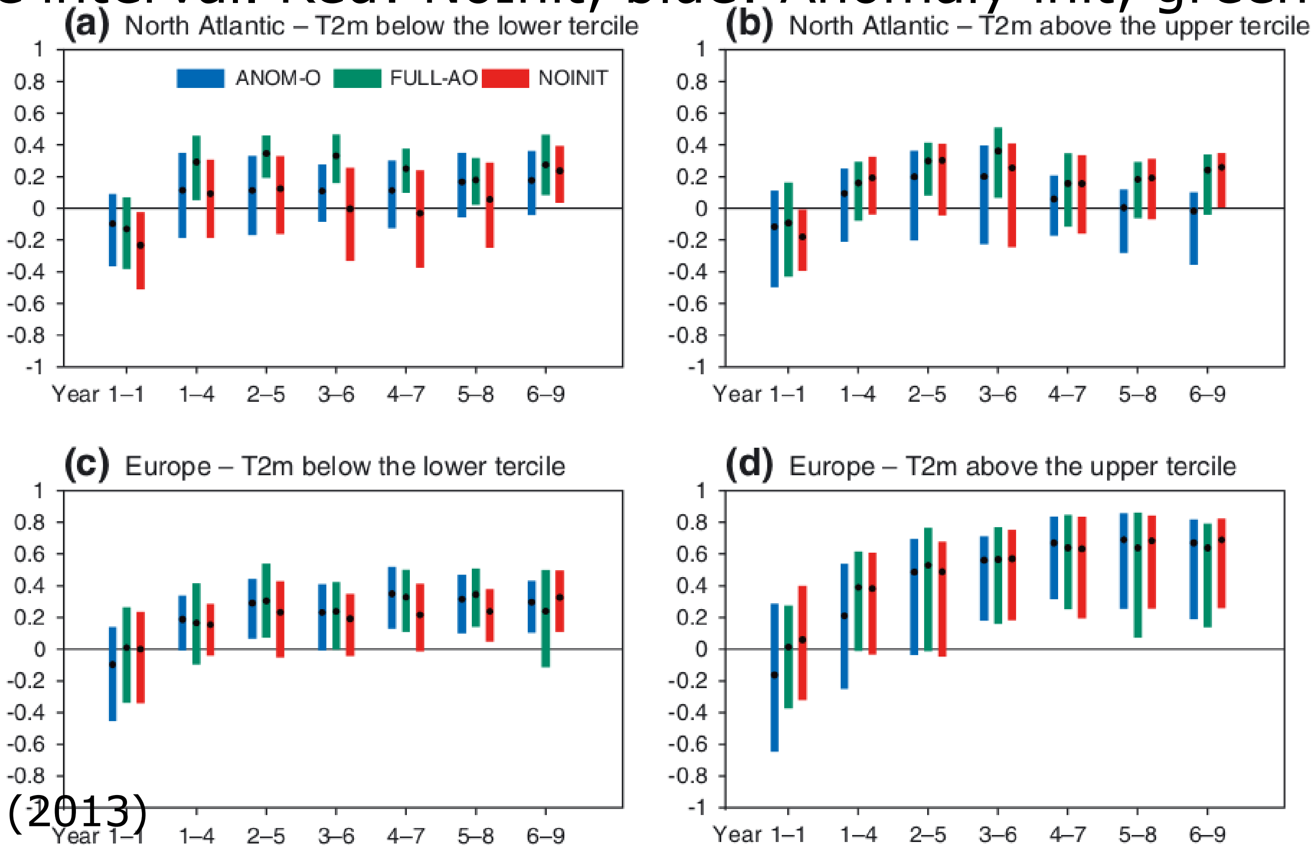


Forecast time (4-year averages)

Doblas-Reyes et al. (2013)

AI/FFI comparison

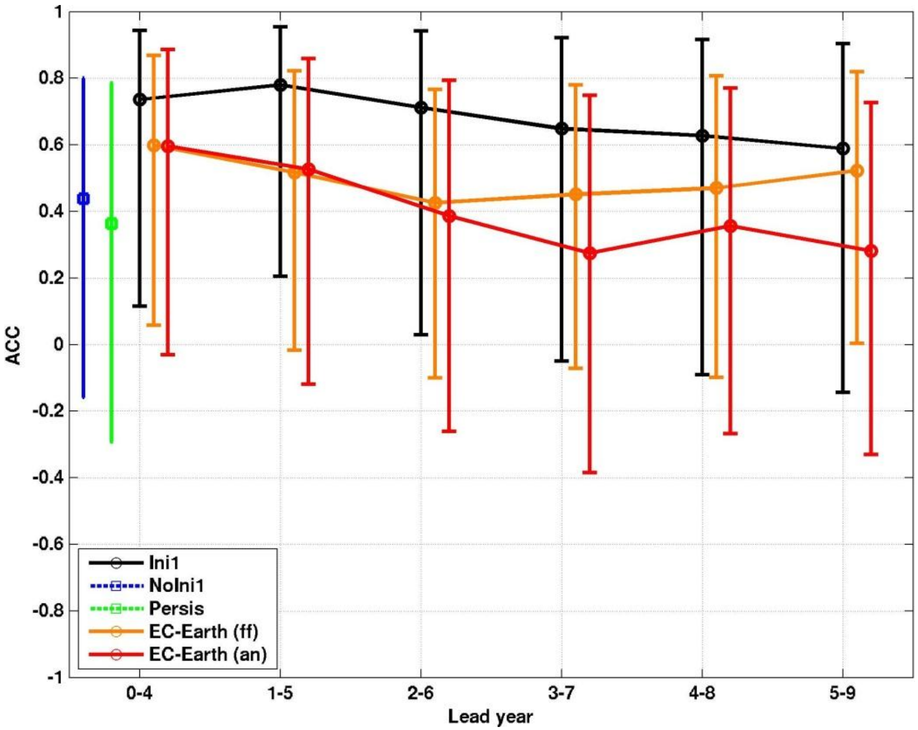
Brier skill score of near-surface temperature for EC-Earth2.3 over (a,b) North Atlantic (30ºN-87.5ºN) and (c,d) Europe (35ºN–75ºN; 12.5ºW–42.5ºE; land only) for events (a,c) below lower tercile and (b,d) above upper tercile as a function of forecast time. The bars indicate the 95% confidence interval. Red: NoInit, blue: Anomaly init, green: Full-field init.

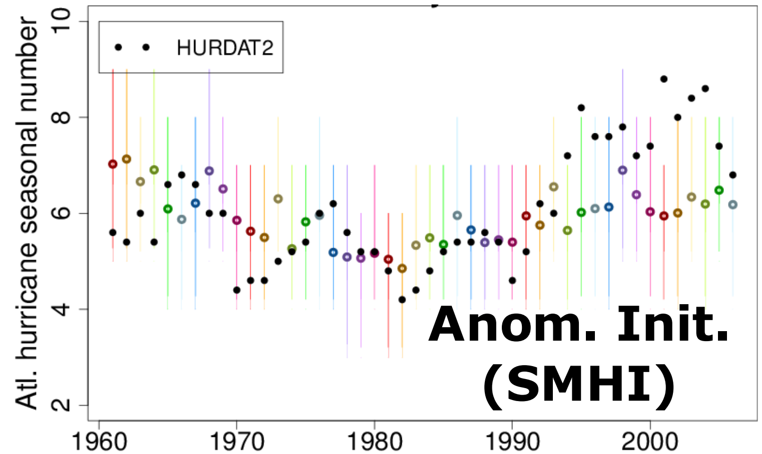


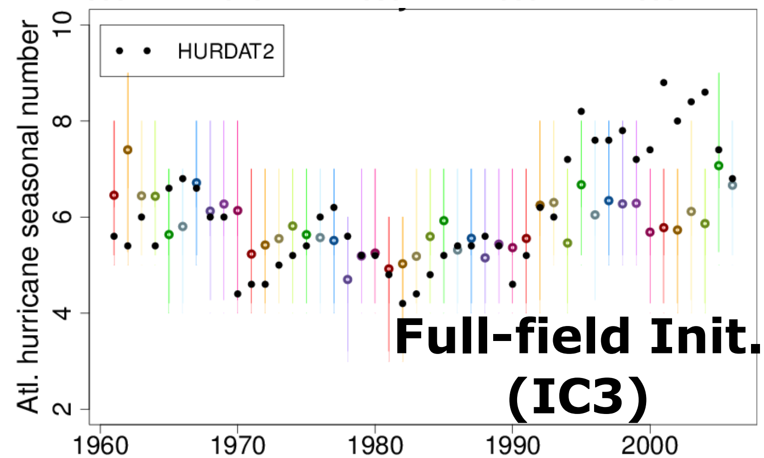
Hazeleger et al. (2013)

Hurricane frequency prediction

Average number of hurricanes per year estimated from observations and from EC-Earth2.3 decadal prediction (forecast years 1-5). The correlation of the ensemble mean for the initialized, uninitialized and statistical predictions are shown with the 95% confidence intervals.



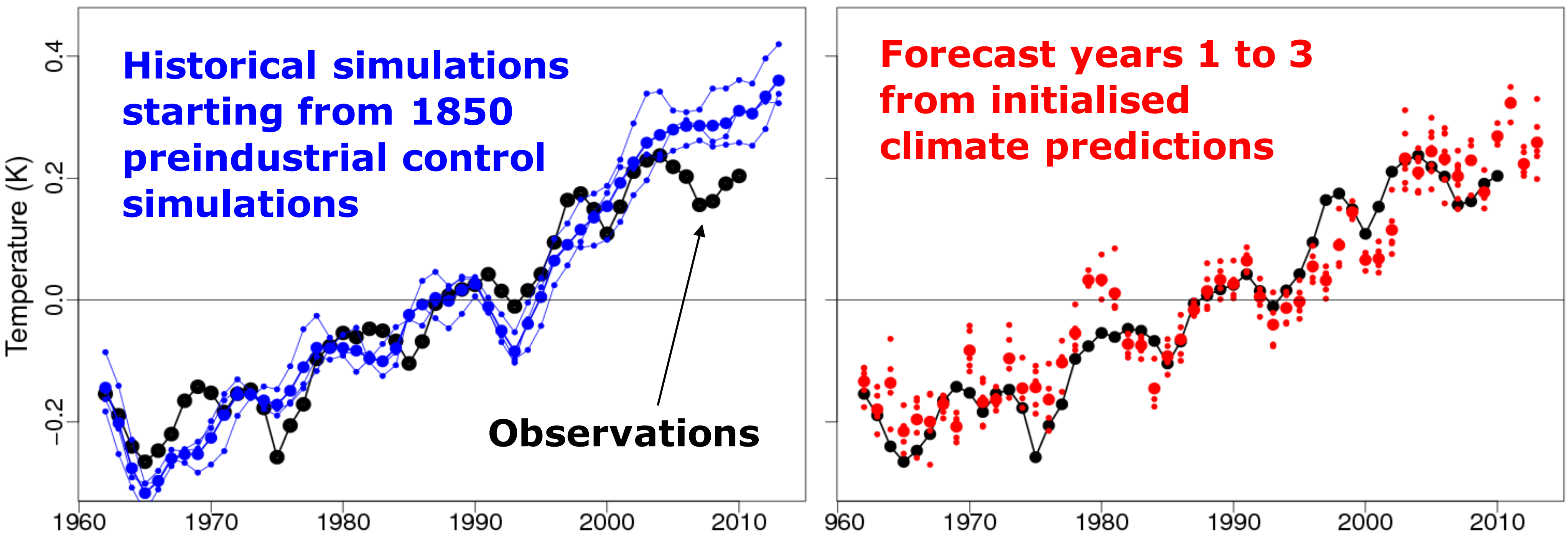




L.-P. Caron (IC3)

Attribution of the XXIst century hiatus

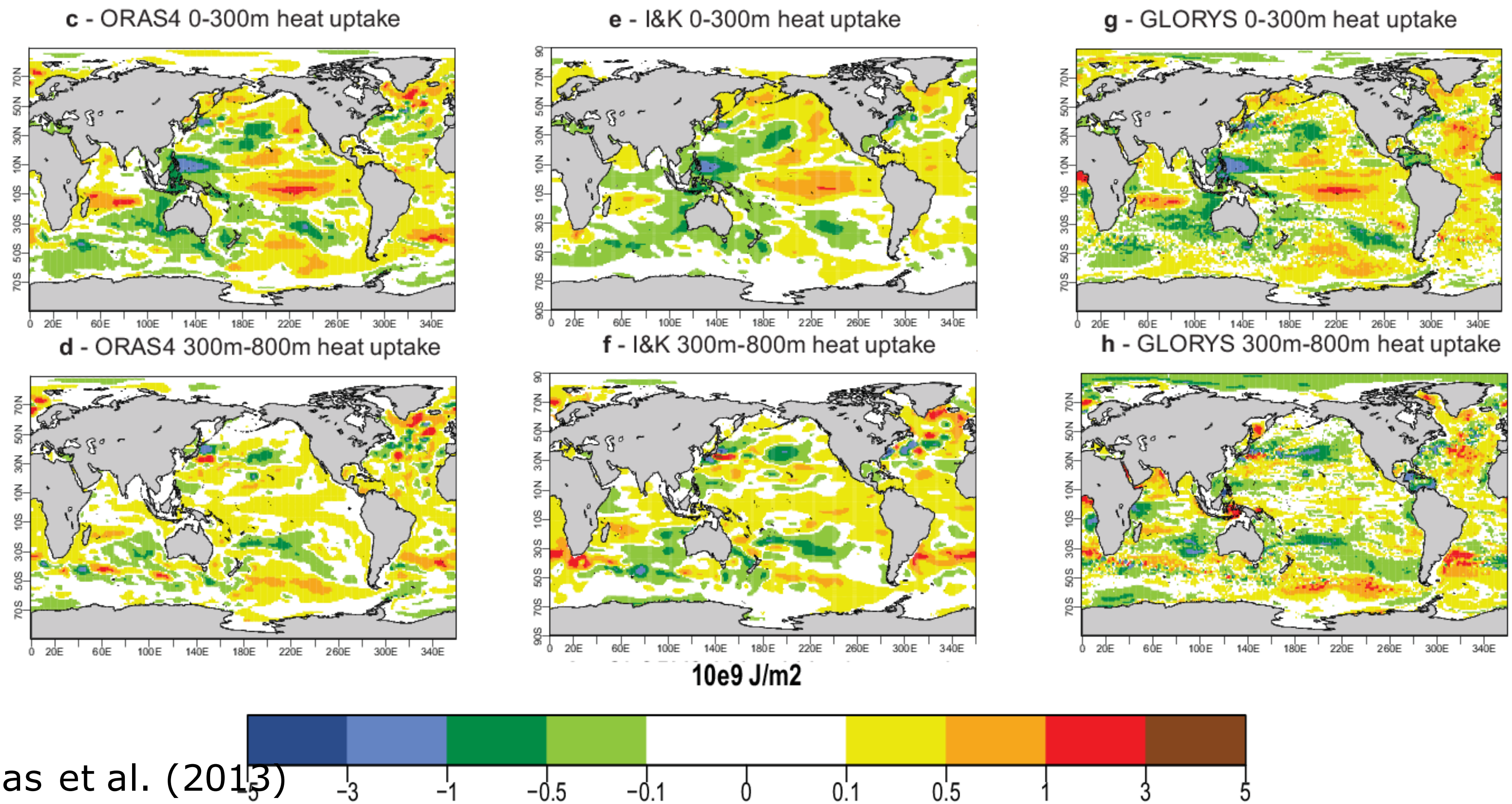
Predictions of the recent global-temperature slow down with EC-Earth 2.3. Global-mean SST from observations (ERSST) and simulations, three-year averages. The experiments suggest an important role of the internal variability, especially the oceans, in the hiatus.



Guemas et al. (2013)

Hiatus in the ocean

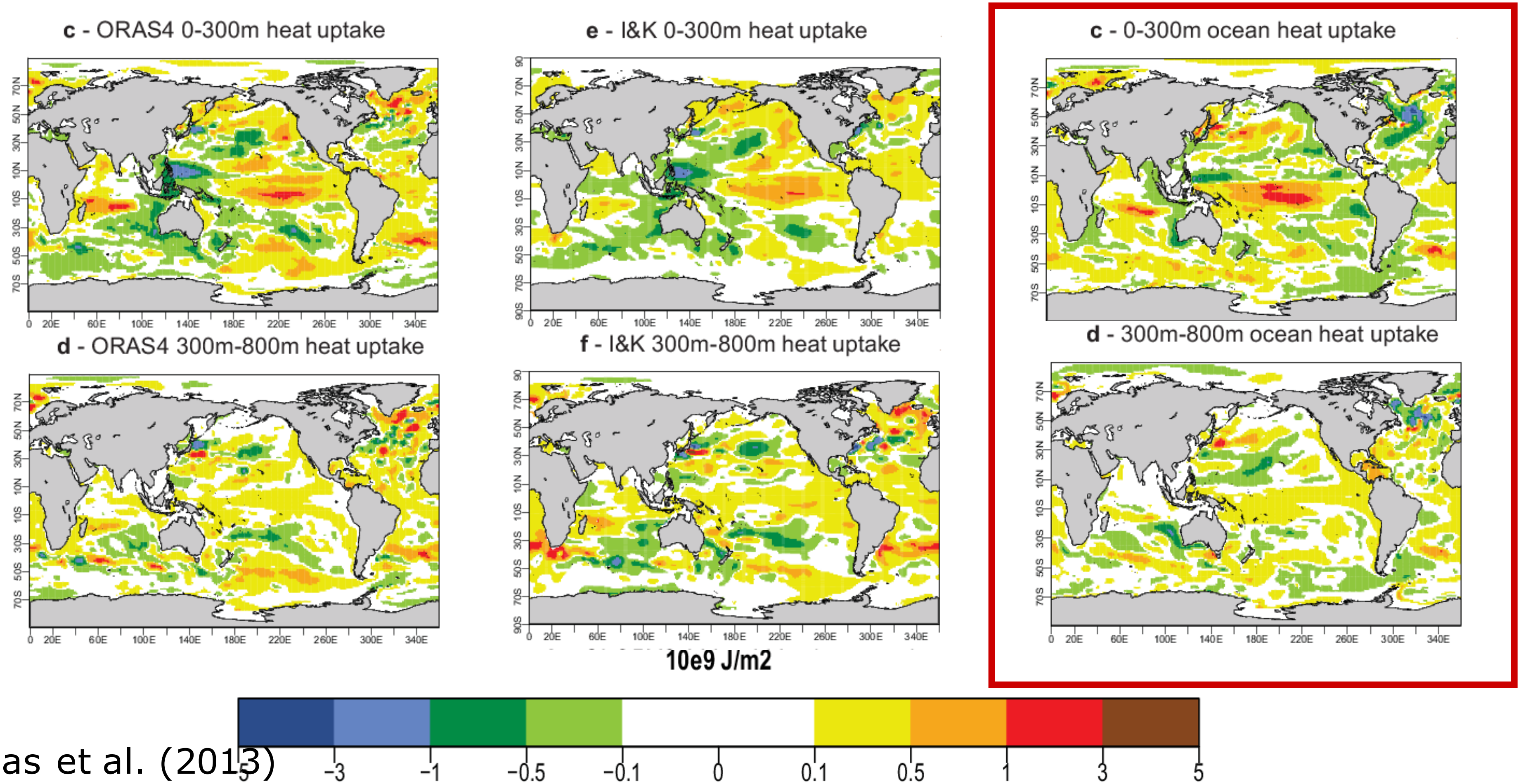
Ocean heat uptake computed as the average of the differences over the periods (2001,2003)-(1998-2000), (2002,2004)-(1999,2001) and (2003,2005)-(2000,2002) for two ocean layers and three reanalyses.



Guemas et al. (2013)

Hiatus in the ocean

Ocean heat uptake as the average of differences over (2001,2003)-(1998-2000), (2002,2004)-(1999,2001) and (2003,2005)-(2000,2002) for two ocean layers, two reanalyses and the EC-Earth2.3 2-4 year predictions.



Guemas et al. (2013)

Real-time decadal predictions

Multi-model real-time decadal predictions for 2012-2016 with respect to 1971-2000.

Forecasts

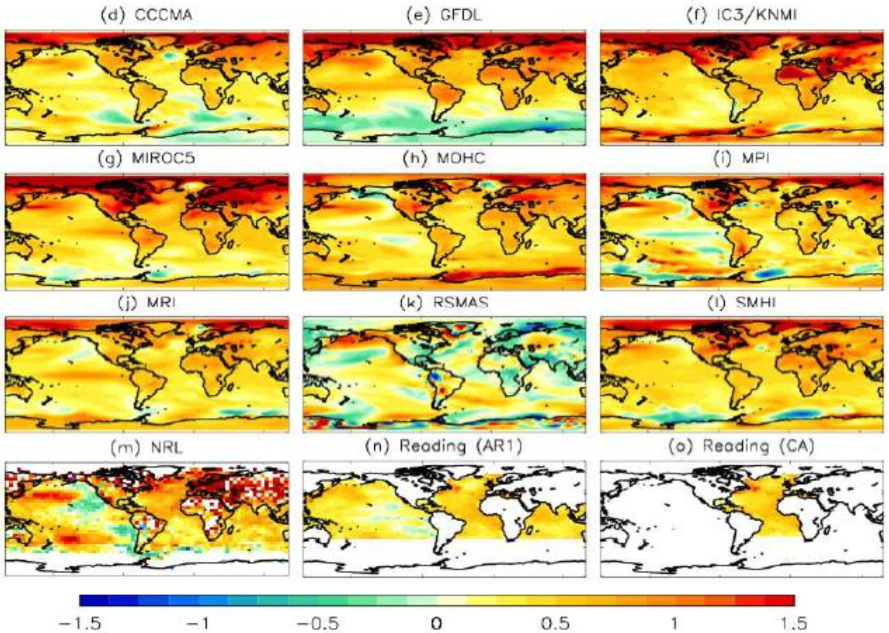


Figure 3: Forecast temperature anomalies (as Fig. 2) for the 5-year period 2012 to 2016.

Impact of initialisation

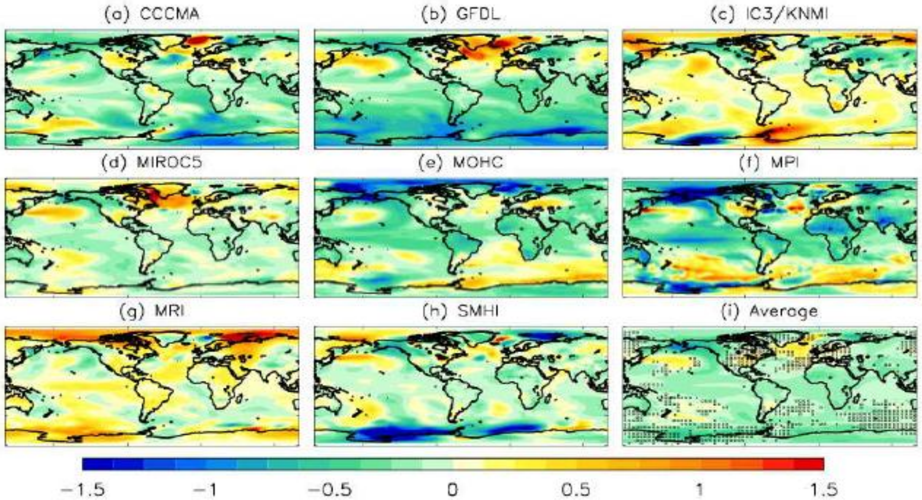


Figure 6: Impact of initialization (initialized minus uninitialized ensemble means) on forecasts of the period 2012 to 2016. Unstippled regions in (i) indicate a 90% or higher probability that differences between the initialized and uninitialized ensemble means did not occur by chance (based on a 2 tailed t-test of differences between the two ensemble means assuming the ensembles are normally distributed).

Smith et al. (2013)

Discussion for CMIP6 decadal MIP

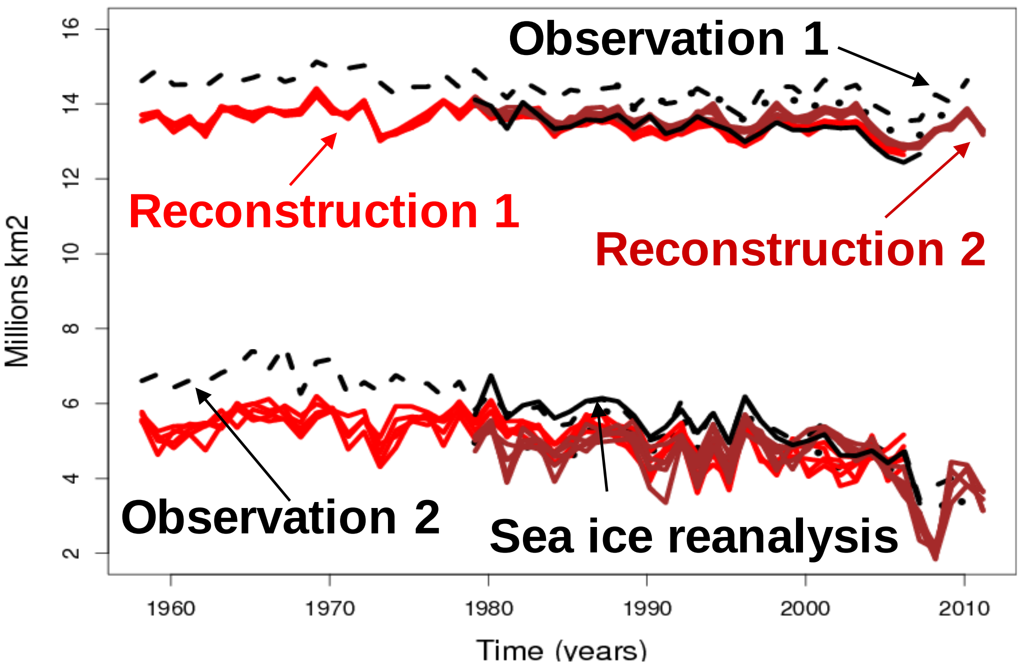
- Formulate an appropriate and relevant scientific question.
- Decadal prediction will benefit from being part of CMIP6:
  - Better understanding (to, hopefully, reduce the drift) the systematic error.
  - Control runs for predictability estimates.
  - Infrastructure: data dissemination, model documentation, diagnostics.
- Other MIPs could benefit from the decadal-prediction MIP:
  - Reduction of the systematic error by understanding the drift sources.
  - Continuous verification of the models.
- Decadal prediction could be a very expensive part of CMIP.
- Real-time decadal prediction exchange should continue and be enhanced (with more variables) whenever possible. Contribute to climate services and WCRP grand challenges.

Initial conditions: sea-ice reconstructions

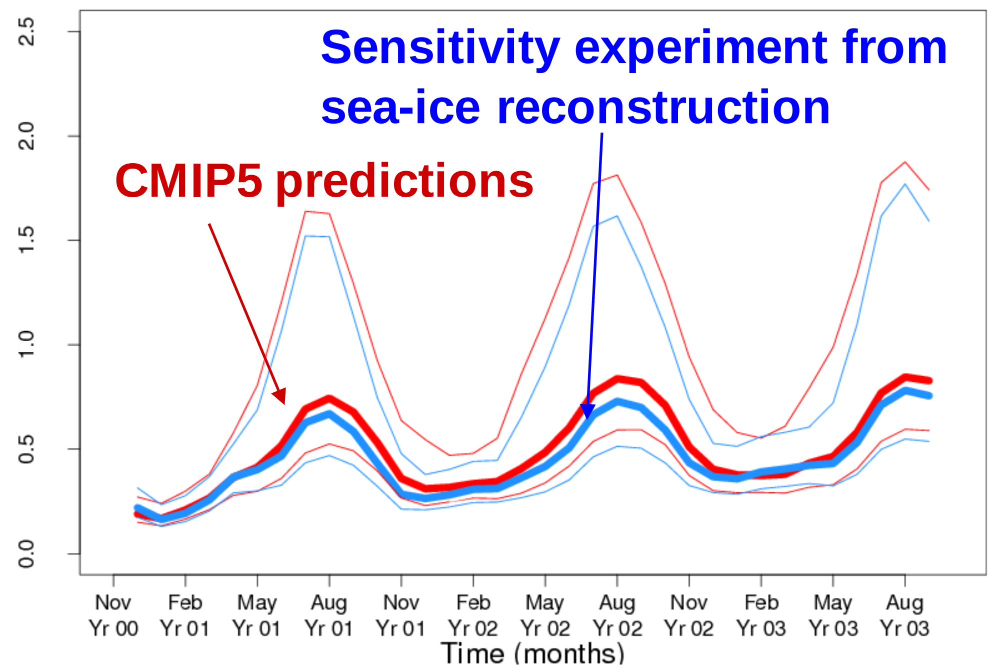
Sea ice simulation constrained by ocean and atmosphere observational data

Arctic sea ice area

March and September reconstruction



Root Mean Square Error of predictions

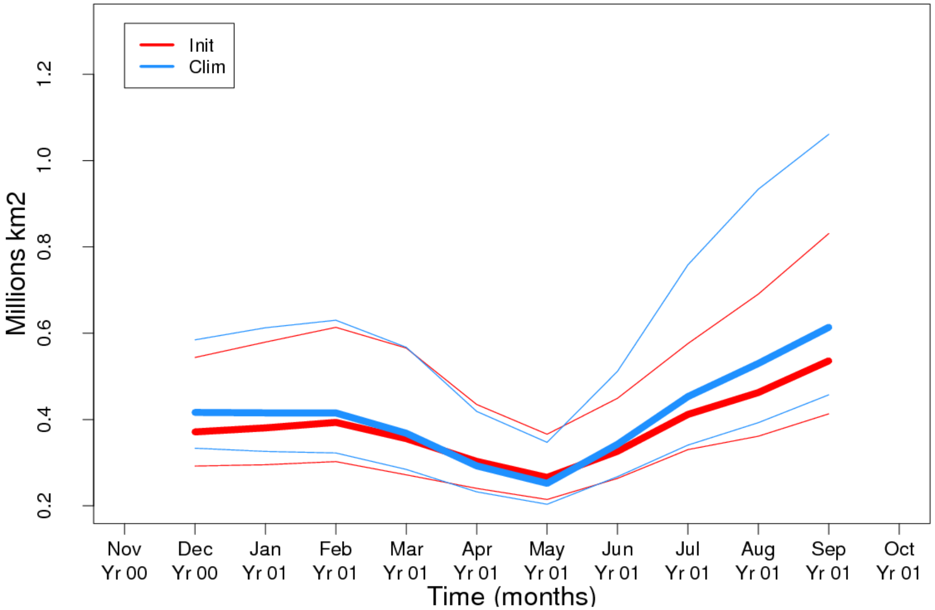


Guemas et al. (2014)

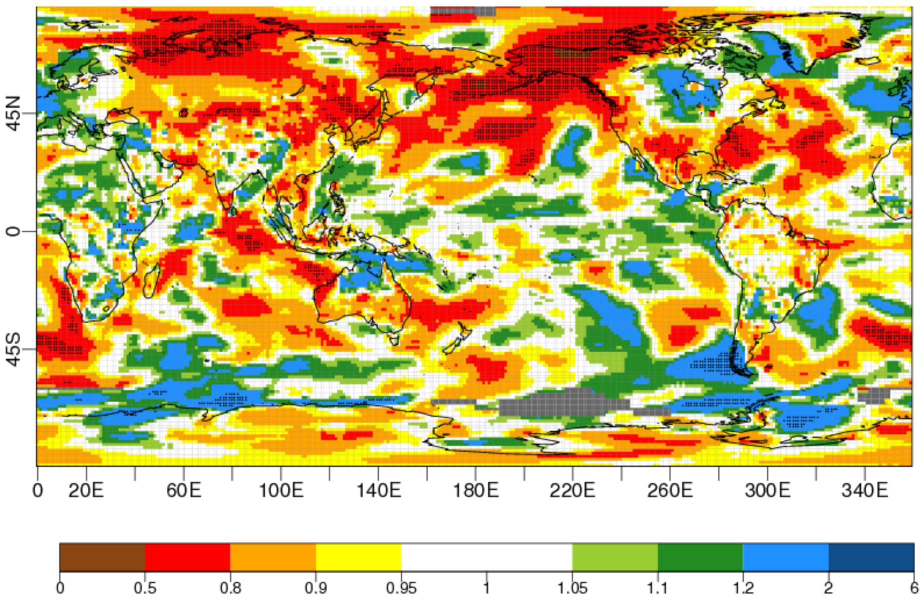
Impact of initialisation: Sea ice

Predictions with EC-Earth2.3 started every November over 1979-2010 with ERAInt and ORAS4 initial conditions, and a sea-ice reconstruction. Two sets, one initialised with realistic and another one with climatological sea-ice initial conditions. Substantial reduction of temperature RMSE in the northern high latitudes when using realistic sea-ice initialisation.

RMSE Arctic sea-ice area



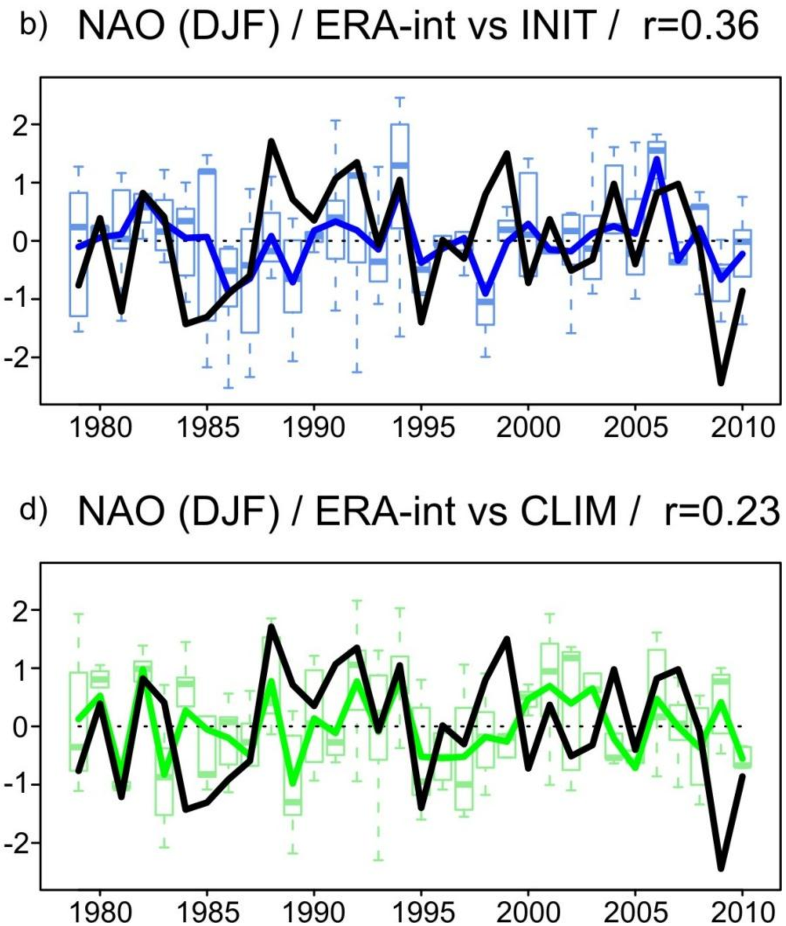
Ratio RMSE Init/Clim hindcasts 2-metre temperature (months 2-4)



Guemas et al. (2014)

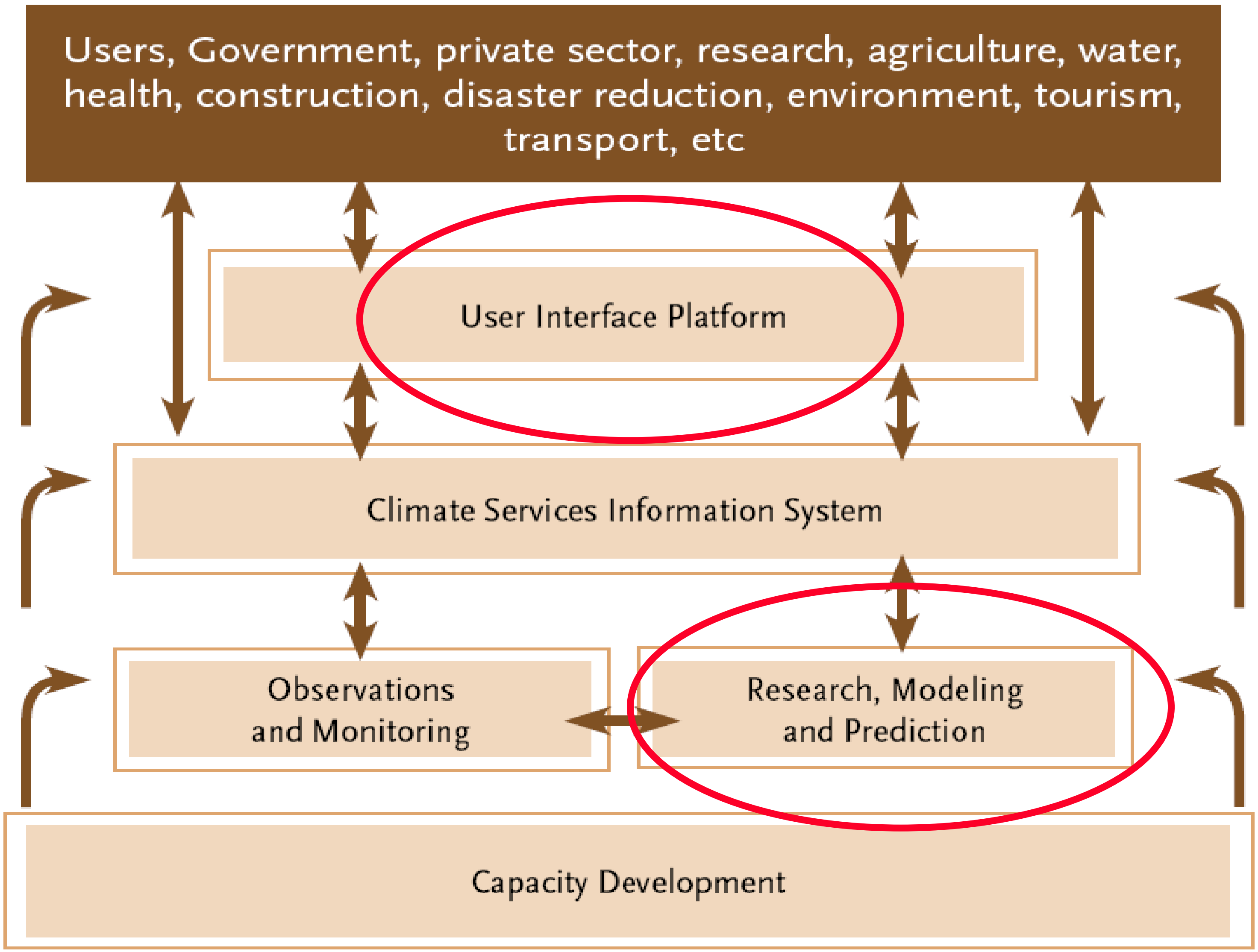
Predicting NA atmospheric circulation

Predictions of DJF NAO with EC-Earth2.3 started in November over 1979-2010 with ERAInt and ORAS4 initial conditions. Two sets, one initialised **with realistic (top) and one with climatological (bottom) sea-ice initial conditions**.



J. García-Serrano (IPSL)

Global framework on climate services



EUPORIAS

- EUPORIAS intends to improve our ability to maximise the societal benefit of climate prediction technologies.
- The project wants to develop a few fully working prototypes of climate services addressing the need of specific users.
- The time horizon is set between a month and a year ahead with the aim of extending it towards the more challenging decadal scale.
- This will increase the resilience of European society to climate change by demonstrating how climate information becomes usable by decision makers in different sectors.
- SPECS and EUPORIAS are part of ECOMS.

Progress on the open fronts

- Work on initialisation: initial conditions for all components (including better ocean), better ensemble generation, etc. Link to observational and reanalysis efforts.
- Model improvement: leverage knowledge and resources from modelling at other time scales, drift reduction. More efficient codes and adequate computing resources.
- Calibration and combination: empirical prediction (better use of current benchmarks), local knowledge.
- Forecast quality assessment: scores closer to the user, reliability as a main target, process-based verification.
- Improving many processes: sea ice, projections of volcanic and anthropogenic aerosols, vegetation and land, …
- More sensitivity to the users' needs: going beyond downscaling, better documentation (e.g. use the IPCC language), demonstration of value and outreach.